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Digital Voice Technologies

Don G3XTT guides readers through the alphabet soup that is the current state of digital voice on the VHF/UHF bands.

Elsewhere in this issue you'll find Tim Kirby G4VXE's review of another digital voice hotspot. He refers to DMR, D-STAR, C4FM, NXDN and P25 as modes that it will handle. But have you ever stopped to wonder what the differences are between the various digital voice modes, why they don't intercommunicate, and what, if any, the advantages are of one versus another?

Why Digital?

Perhaps one of the first questions to address is why we want to send voice digitally at all. After all, AM, SSB and FM seem to have worked pretty well for most of the history of amateur radio. They can be generated relatively easily and be received on most radios, while on VHF and UHF (and even on the 10m HF band) we have a well-established network of FM repeaters.

We are also probably well aware that the broadcast world are having trouble persuading us that digital is the way to go for radio (although digital TV is now well established). It's partly because a number of 'standards' are competing (DAB is primarily a UK-led standard, while Radio Mondiale, used on HF, has its limitations). And a digital receiver is an extra expense if you already have a house full of transistor radios from years gone by (and ditto in your car), while for fixed use you probably just want to plug into the internet.

For radio amateurs, the main attraction of digital, so far as I can see, is that it allows straightforward networking, enabling calls to be set up across the globe, using the existing internet as the backbone. The necessary routing information can be embedded into the digital bitstream alongside voice and there is scope for coding and carrying other sorts of traffic too, such as APRS, images or other types of data. Another attraction might be that, using hotspot technology, a station can be established anywhere you have an internet connection, ideal if your location is one where it is impossible or challenging to erect HF or VHF antennas.

Fig. 1: The Kenwood TH-74E, one of the first non-Icom radios to include D-STAR capability.

How is it Done?

Most of you will realise, particularly if you are regular readers of this magazine, that the underlying principles of digital transmission of voice are easy to understand. The analogue voice waveform is sampled in an analogue-to-digital converter (ADC) and the digital bitstream can then be modulated onto an RF carrier. But there's the rub. There are many ways in which the sampling can be done and there are a number of ways that the data can then be applied to the carrier. Which means that there are potentially hundreds, if not thousands, of combinations that could be used to make it happen. The choice depends on many factors such as the quality of voice transmission required, the type of propagation that is likely to be encountered during the radio part of the connection and so on. It also matters whether the system is only intended to carry speech or whether data transmission is also a requirement. Speech can afford transmission errors and still be perfectly readable whereas data transmission must be more robust because while the human ear can cope with occasional transmission errors, computers tend to be less sympathetic!

Communications theory tells us that an audio waveform has to be sampled at, as a minimum, twice the highest frequency likely to be encountered. If we want to send speech of up to 3kHz, say, then we need to sample at 6,000 samples/second or better. The samples will then have to be encoded and the number of bits we use to encode each one will depend on how accurately we want to reproduce the speech at the other end. All this means that transmitting high-fidelity classical music, for example, will require a very high bit rate. Fortunately, communication quality speech is much less demanding. What's more, there is quite a lot of 'redundancy' in speech so a number of methods have been developed to make the whole process more efficient.

Genesis of Systems

It's important to be aware that some of the systems being used in the amateur radio world had their origins in the commercial world while some were developed specifically for the amateur market. Why does this matter? D-STAR is essentially an Icom initiative although the standard is open to others to use (as Kenwood have done in, for example, the TH-D74 handheld, **Fig. 1**). Yaesu have chosen to go their own way

with System Fusion, which Tim G4VXE has been covering in recent months. What both have in common is that the radios manufactured for these systems generally offer FM capability too and, indeed, the System Fusion repeaters are also capable of FM as well as Fusion operation. These two systems have also been developed with amateur radio callsigns and requirements (such as APRS) in mind.

In contrast, P25 (an older technology used by Motorola and other commercial manufacturers, **Fig. 2**), NXDN (another commercial system, albeit in limited use in the amateur radio world, **Fig. 3**) and DMR (increasingly used in amateur radio) were all developed for commercial use and transceivers employing them reflected this. For example, there would normally be no straightforward way for the user to change frequency (unless required for day to day use). A group of radios would normally be programmed to a specific channel (or channels) for company use and the last thing the company wants is for employees to start changing the programming! Similarly, the radios were purely DMR and even this comes in more than one guise, not so much in the actual encoding of the speech but in the way they network. Motorola's name for DMR is MOTOTRBO while, for example, Hytera refers to it as Hytera DMA. Each company has its own take on the implementation of the 'standard'. The following link gives more information, including an explanation of Tier 1, Tier 2 (as used in the amateur radio world) and Tier 3 DMR architectures. **https://tinyurl.com/yxzpqv6n**

Consequences

The consequence is that DMR radios that come to the amateur market second-hand from the commercial world, while usually competitively priced, are likely to require specialist programming tools and lack the flexibility of transceivers made specially for the amateur radio market. Thus, for example, it might make sense for a club with the necessary expertise to bulk buy ex-commercial DMR sets and program for the local DMR repeater for members' use. But those sets won't help a member who travels the country and wants to use it elsewhere. The good news, though, is that some amateur radio manufacturers are now offering DMR sets at attractive prices – we have reviewed some of them here in *PW* – and those are generally more geared to amateur radio requirements. So it's not clear cut – we are starting to see some DMR transceivers that can be programmed from the keypad without needing a computer and many include FM capability too (The Anytone AT-D868UV, **Fig. 4**, reviewed in last October's issue, is a good example of both aspects).

Fig. 2: An Icom P25 commercial set.

What it all means is that your choice of which option to take, should you decide that digital voice is for you, will depend on several factors. An obvious consideration is which system is in use in your locality, particularly if you belong to a club that has made a choice and/or if there is a digital repeater accessible close by. Another factor is whether you want to be able to travel with your digital radio and easily reprogram it for the repeater(s) you run across along the way. A third might be the specific use(s) that you want to put the radio to, such as APRS beaconing. A fourth will be your wishes for international networking.

Having said all that, and having explained that the various encoding methods are mutually incompatible, if you read *PW* regularly you will have come across reviews of hotspots. As I said right at the start, we review one in this very issue. Most of these will accept any of the digital standards and allow you to connect to the relevant global network, so that, for example, you can use your DMR or D-STAR handheld to chat with a DMR or D-STAR user in the USA or Australia. I gather from one of the leading UK vendors that there is quite a community of 'hotspotters' nowadays, including Foundation licensees, who simply use their amateur radio licence as a way of linking across the living room to a hotspot but enjoying global communication, nevertheless. Personally, while I understand the fun of this, I'd love to see those folk move on to other aspects of the hobby – hopefully many do so in the fullness of time. But there's no denying the magic, even in this day and age, of enjoying global communication with fellow enthusiasts in a simple and, effectively, cost-free way.

Technologies

Anyway, given that I am running this article under the *Technical for the Terrified* banner, let's end with a few of the technical bits. Traditional amplitude modulation is based, as you will all know, on varying the amplitude of an RF carrier in time with the audio (voice) signal. This process results in (and the maths shows this too) a carrier and two sidebands, both carrying identical information. For example, a 1kHz tone applied to a 1MHz carrier will result in carrier plus two new signals, one 1kHz above the carrier in frequency and one that is 1kHz below. SSB, then, is simply this but with the carrier and one of those sidebands removed, given that the carrier bears no information content and both sidebands have identical information. In contrast, FM involves changing not the amplitude but the frequency of the RF carrier in synch with the modulating audio. This offers a number of advantages over AM or SSB, particularly for high quality broadcasting, because the carrier can be allowed to swing a long way either side of its nominal frequency, allowing more accurate reproduction of, say, music with its large dynamic range and covering several octaves. In amateur radio practice, FM channel spacing started at 25kHz (as used back then in the commercial world) and

Fig. 3: A Kenwood ad for NXDN transceivers.

has now settled on 12.5kHz, given better and more stable equipment.

A third method is phase modulation, where neither the amplitude nor the frequency is shifted in synch with the modulation, but rather the phase of the carrier. This is not used for voice transmission but you will often find it as the modulation method of choice for data transmissions – QPSK (Quadrature Phase Shift Keying) and PSK (as in, say, PSK31 and PSK63) being terms that you will have seen, even if you haven't operated those modes.

Table 1 summarises the key aspects of the various systems I have discussed. I have taken it from an article in the April 2015 issue of *QST*. While digital voice has moved on in some ways since then, the underlying technologies of each system are the same. The codec (Coder/Decoder) is the method for turning the digital stream from the ADC into the particular coding system in use (and doing the opposite for received data). I won't go into detail here but AMBE stands for Advanced Multiband Excitation while IMBE is Improved Multiband Excitation. You can find out more from Wikipedia and other sources where you will learn, for example, that AMBE was developed for use by the Inmarsat (maritime satellite) and Iridium commercial satellite systems. Its use requires a licence from Digital Voice Systems Inc, so there has been criticism in some amateur radio circles that D-STAR isn't actually as 'open' as the manufacturers would like us to believe.

The data stream from the Codec then needs to be applied to the RF carrier. 4-FSK means, as you might guess, that the method employed is 4-tone frequency-shift keying, while 2-GMSK is a two-tone Gaussian minimum shift keying, a variation that is claimed to occupy less bandwidth.

The Sharing column refers to the way in which the common bandwidth is shared. FDMA (Frequency Division Multiple Access) indicates that different transmitters operate on different frequencies (yes, a fancy name for what happens on most of our bands!) while TDMA (Time Division Multiple Access) has different transmitters sharing a carrier frequency but interleaving their transmissions which, as you'll understand, requires accurate timing but does, for example, allow DMR repeaters to carry two voice channels on the same frequency (you'll hear this referred to as Timeslot 1 and Timeslot 2).

The last column, headed Access, is the digital voice equivalent of CTCSS or DCS tones that you'll be familiar with in the analogue world of FM repeaters. As I explained earlier, D-STAR and Fusion use amateur radio callsigns as the basis, for obvious reasons, but the other systems, having originated outside the world of amateur radio, use a variety of other identification and routing protocols.

Type	Codec	Modulation	Sharing	Access
D-STAR	AMBE	2-GMSK	FDMA	Callsigns
DMR	AMBE+2	4-FSK	TDMA	Colour codes
System Fusion	AMBE+2	4-FSK	FDMA	Callsigns
NXDN	AMBE+2	4-FSK	FDMA	6-bit RAN
P25 Phase 1	IMBE	4-FSK	FDMA	12-bit NAC
P25 Phase 2	AMBE+2	4-FSK	TDMA	12-bit NAC

Table 1: Digital Voice Systems Compared

Fig. 4: The Anytone AT-D-868UV has both DMR and FM capability.

The Bottom Line

I hopethis overview helps you to understand the key differences between the various digital voice systems. Each system, as you'll have seen, has its pros and cons so you have some thinking to do before taking the plunge. Unfortunately, the sheer variety of systems has also diluted VHF/UHF activity in that, while there may still be as many amateurs using VHF and UHF repeaters and simplex as before, they can't now all intercommunicate. In fairness, other factors are at play too, such as the large-scale migration to FT8 operation at VHF. How it will all pan out remains to be seen. Will one system come to predominate (as VHS did over Betamax for those of you old enough to remember) or will they simply continue to coexist on our bands? This latter may well be the case because we are starting to see the emergence of multi-protocol reflectors, enabling someone with, say, a D-STAR radio to connect and speak to someone using a Fusion radio connected to the same reflector. In other words, although the protocols are different, the huge processing power of modern PCs means that protocol conversion can be cost-effective and may serve to bring those disparate groups together after all. Watch this space!